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A study on the efficiency of multiple degrees of freedom Ultrasonic Motor using combination of travelling wave type stators

複数のステータを用いた進行波型多自由度超音波モータのすべりに関する研究

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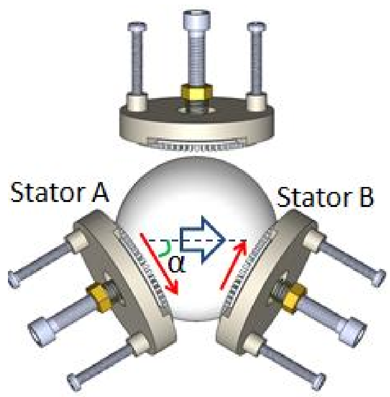
1. Introduction

Ultrasonic motor (USM) is one of the powerful actuator to realize the multi degree of freedom(MDOF). Recently, many research groups reported on the MDOF USM. In the reports, driving structures of MDOF USM are two types, which one structure is the combination of single motion stators, and the other is the single stator. The single stator type realizes MDOF motion using the combination of the degenerated different resonance modes of the stator. And, hence, the structure is very compact and also, can reduce the slip or other loss. However, it is difficult to adjust the resonance frequency of the different modes so as to match the frequency. And also, a preload structure is a severe problem in the single stator type MDOF USM. In the combination of single motion stators type, the MDOF motion is achieved by the resultant vector of each stator rotation vector. Preload structure is considerable easy by arrangement of the stators. The power suit application using MDOF USM already has been reported. However, the combination of single motion stators type occurs severe slip and efficiency of USM is low since the motion direction of the rotor is not coincident to motion of the stators.

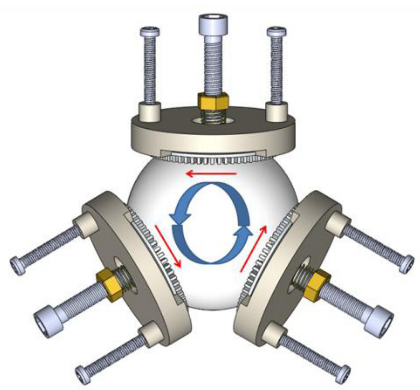
In this report, the slip and the efficiency of the combination of single motion stators type MDOF USM is investigated. The variation of efficiency is measured by changing the driving conditions of the stators.

2. Driving principle of the motor

Figure.2 shows configuration of the stator. Three same stators, we call the stator A,B and C, are used for the MDOF USM. Figure.1 shows the driving principle of the motor. The rotation direction is realized by the resultant vector of the driving force of each stator. The rotation direction and the rotation speed are controlled by changing the vibration displacement of each stator. As shown in Fig.1(a), the driving direction of the single stator is indicated by thin red arrow and the rotation direction, that is the resultant vector of two driving direction of the stator, is indicated by the thick blue arrow. The angle of rotation direction against the driving force vector is indicated by the angle α. The angle α is controlled by the ratio of the driving force in the stator A to the force in the stator B. In the case that three stators are employed as shown in Fig.1(b), the rotation direction is determined by the resultant vector of the driving forces of three stators.



(a) Driving two stators



(b) Driving three stators
(thin arrow(red):driving direction of the stator, thick arrow(blue):the rotor rotates)
Fig1. MDOF motor driving

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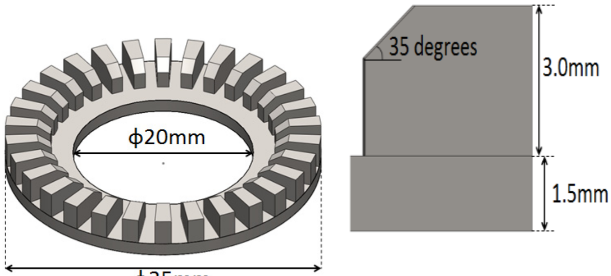

(a)configuration

(b)projection

Fig2. configuration and dimensions of stator

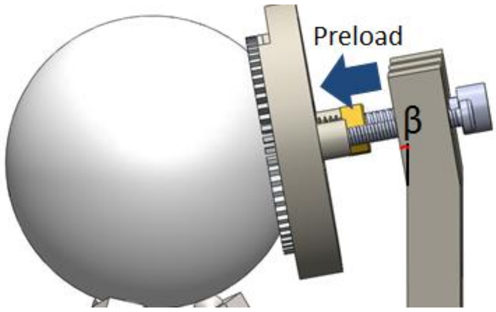

Fig3. Contact of the stator and the rotor gave slope

3. Dimensions and configuration of the motor

Dimensions of the stator was determined by finite element analysis (FEM). Figure 2(a) shows the stator is the ring whose inner diameter is φ20mm, outer diameter is φ35mm and thickness is 1.5mm. Figure 2(b) shows the dimensions of projection of which height is 3.0mm. The inner corner of the projection is chamfered at 35 degree of angle in order to improve the contact condition between the rotor and the stator. The number of projections on the stator is 30.[1][2] In the analysis of FEM, the resonance frequency of the stator in the 9th mode was 57.84kHz. The diameter of the employed a ball rotor is φ80mm. Figure 3 shows the preload structure. Each stator is supported by the quadrangular prism which upper part is inclined as shown in Fig.3. [3]

4. Characteristics of the motor and measurement of slip loss

The resonance frequency of the stator A are 60.00kHz.And those of the stator B are 62.12kHz and stator C are 61.22kHz. There was a 3～4kHz error in the observation result of each stator, and the analysis result by FEM. The rotor is forced on ring type stator with the preload of 1.96N at 100V of applied voltage, and torque measurement was performed. The torque measurement result was as follows. The stator A was 12.61N・mm, the stator B was 12.44N・mm and the stator C was 8.40N・mm.

Research was measured when outside diameter of two stators is φ60mm, ball rotor is φ80mm and the pole is tilted 10 degrees. The measurement result became as it is shown in figure4 , and the loss rate was 56.1% when angle of α=30 degrees in figure1(a). With these results in figure.5 when it is made to change with the angle α= 15, 30, and 45 or 60 degrees, loss rate becomes larger with larger slope.

In future research, it is examined how the difference in the size of the stator and the ball rotor, the difference by slope of the stator (angle β) and the angle α of the stator and the rotation direction of ball rotor will concern the slip.

References

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2.H ISHIDA et al:JSPE.(Vol.73 No.2 2007)275-280

3.H WADA et al:JSPE.(Vol.67 No.4 2001) 654-659

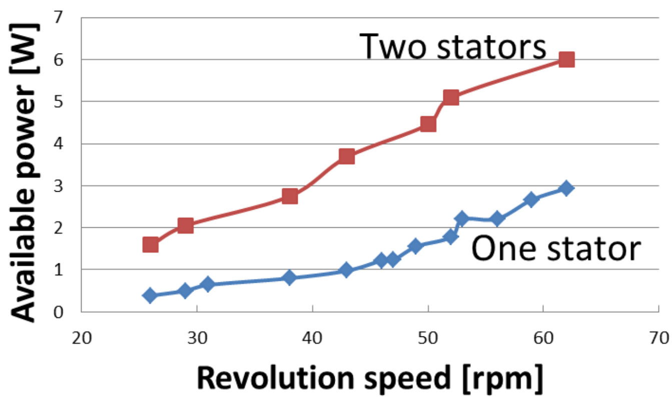

Fig4. Compare one stator and two stators

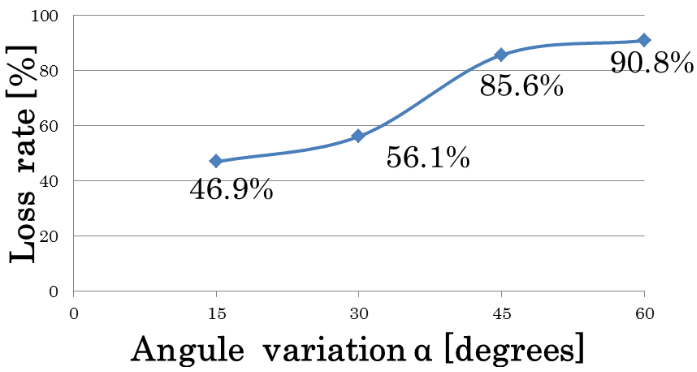

Fig5. Loss rate when varying the angle α